part Of #3

(marked copy of sub spec.

VERSION WITH MARKING TO SHOW CHANGES MADE

(USSN 09/919,868)

IN THE TITLE:

The title has been amended as follows: METHOD FOR REDUCING LINE EDGE ROUGHNESS OF PATTERNED PHOTORESIST.

IN THE SPECIFICATION:

Paragraph beginning at line 10 of page 1 has been amended as follows:

This invention relates generally to method for reducing line edge roughness of patterned photoresist, and particularly relates to method for improving precision of pattern of patterned photoresist without changing patterned photoresist material or changing both develop process and bake process.

Paragraph beginning at line 18 of page 1 has been amended as follows:

For semiconductor fabrication, patterned photoresist is an indispensable part for transferring pattern of a mask into a semiconductor substrate. Because the pattern of patterned photoresist essential is the pattern of the semiconductor substrate, how to ensure the pattern of patterned photoresist is equal to (pattern of)the mask is an important key for whether pattern is accurately transferred or not.

Paragraph beginning at line 24 of page 1 has been amended as follows:

Because practical semiconductor fabrication is limited by numerous factors, such as available materials of both patterned photoresist and a developer, unavoidable errors during both developing process and priming process, standing wave phenomena, and non-uniform distribution of polymers

which are composition of patterned photoresist. It is (often-seen)usually that some trenches are existent in formed patterned photoresist (which)that is patterned. Owing to location and number of trenches are random distributed, disadvantages such as non-smooth surface and line width variation (are)is occurred and usually is called as line edge roughness. Fig. 1A and Fig. 1B illustrate ideal shape of patterned photoresist, and both Fig. 1C and Fig. 1D qualitatively show real shape of patterned photoresist while line edge roughness is happened. Herein, all figures are not illustrated in according to practical scale for emphasizing possible variation, patterned photoresist is formed on the semiconductor substrate 10, shape of patterned photoresist 11 could be any shape, and both location and shape of trenches 12 are random distributed.

Paragraph beginning at line 13 of page 2 has been amended as follows:

Obviously, (because) line width variation and non-smooth surface changes the shape of patterned photoresist, increases the critical dimension of patterned photoresist, and disagrees the pattern on the semiconductor substrate with the actual shape. (is changed by line width variation and non-smooth surface, critical dimension of pattern of patterned photoresist would be increased and sequentially formed pattern on semiconductor substrate would be in disagreement with the actual shape.) Thus, conventional semiconductor fabrication usually repairs patterned photoresist to reduce(, even) or eliminate(,) line edge roughness of patterned photoresist before pattern of patterned photoresist is transferred into the semiconductor substrate.

Paragraph beginning at line 22 of page 2 has been amended as follows:

Conventional semiconductor fabrications reduce line edge roughness of patterned photoresist by modifying temperature and/or period of soft bale process, hard bake process, and/or post exposure bake process. However,

because standing wave phenomena is unavoidable while patterned photoresist is exposed by light and improvement is limited by the available material of patterned photoresist, conventional semiconductor fabrication could not effectively reduce, or even eliminate, line edge roughness of patterned photoresist.

Paragraph beginning at line 2 of page 3 has been amended as follows:

As (a) the following summary, (because) the conventional semiconductor fabrication could not prevent defects of line edge roughness.(,) (but e)Effects of line edge roughness are more and more serious while critical dimension of semiconductor device being continuously shrunk(shrink), it is desired to develop a new method for reducing line edge roughness of patterned photoresist.

Paragraph beginning at line 12 of page 3 has been amended as follows:

One main object of this invention is to (effectively) reduce line edge roughness of patterned photoresist effectively.

Paragraph beginning at line 15 of page 3 has been amended as follows:

Another main object of this invention is to improve precision of (pattern of) patterned photoresist without changing patterned photoresist material or changing both develop process and bake process.

Paragraph beginning at line 19 of page 3 has been amended as follows:

Still one main object of this invention is to (effectively) reduce line edge roughness by filling, to accomplish good control ability for control line width of patterned photoresist effectively.

Paragraph beginning at line 23 of page 3 has been amended as follows:

This present invention provides a method of reducing line edge roughness of patterned photoresist. Initially, provide a patterned photoresist which (at least) has at least a trench and is located on the substrate.(, and t) Then fill these trenches so let that trenches are totally filled by an additional material, wherein the additional material is easily to bond with the patterned photoresist. Next, remove parts of the additional material (which is)that are located on patterned photoresist and the substrate. Finally, treat the additional material to enhance (so let) that adhesion between the additional material and patterned photoresist(is enhanced) after the additional material is treated. Because trenches on patterned photoresist are filled by the additional material, real pattern of patterned photoresist could be equal to the ideal pattern, and then precession of patterned photoresist is enhanced.

Paragraph beginning at line 5 of page 4 has been amended as follows:

Furthermore, this embodiment could be further modified as follows: omit step of removing part of the additional material while only trenches are filled by the additional material; and omit step of treating the additional material while adhesion between the additional material and patterned photoresist is good.

Paragraph beginning at line 18 of page 4 has been amended as follows:

Fig. 1A to Fig. 1B are qualitative illustration about ideal shape of patterned photoresist;

Paragraph beginning at line 21 of page 4 has been amended as follows:

Fig. 1C to Fig. 1D are qualitative illustration about practical shape of patterned photoresist;

Paragraph beginning at line 4 of page 5 has been amended as follows:

Because choice of patterned photoresist material, baking time and baking temperature are strongly related to whole process for transferring pattern from the mask into patterned photoresist, none of them could be decided only in accordance with requirement for preventing line edge roughness. Thus, this present invention reduces line edge roughness of patterned photoresist from another approach.(:) First, (still) use conventional semiconductor fabrication to form photoresist (pattern) which has line edge roughness such as trenches, non-smooth surface, and line width variation. Then, (after pattern is transformed into patterned photoresist,)fills trenches(, (include) holes(),) in patterned photoresist by an additional material(, so let) to reduce and eliminate non-smooth surface and line width variation (are reduced or even eliminated). Finally, transferring the pattern into the semiconductor substrate (uses both) the patterned photoresist and the additional material(as a mask to transfer pattern into semiconductor substrate).

Paragraph beginning at line 18 of page 5 has been amended as follows:

(In short, c)Conventional semiconductor fabrication (usually directly)always uses patterned photoresist as the mask (used by) during an etch process and an implant process, (and then) so that patterned photoresist which is deformed by line edge roughness (reasonably) could not(accurately) transform the pattern of the mask into the semiconductor substrate accurately. In contrast, thus present invention repairs deformed patterned photoresist by filling trenches with an additional material, that is easily to bond with the patterned photoresist, and then uses both patterned photoresist and the additional material as the mask (used by)during etch process and implant process. Because trenches are filled by the additional material, the pattern transformed into the semiconductor substrate is (essentially) similar with the desired pattern, only when(except) patterned photoresist is too deformed, too wide or too curved to be repaired by filling the additional material, or pattern of patterned photoresist is significantly different from pattern of the mask.

Paragraph beginning at line 3 of page 6 has been amended as follows:

One preferred embodiment of this invention is a method for reducing line edge roughness, (at least includes) with following steps.

Paragraph beginning at line 6 of page 6 has been amended as follows:

As shown in Fig. 2A and Fig. 2B, providing patterned photoresist 21 which is located on the substrate 20 and (at least) has at least one trench 22. Herein, trenches 22 (could be located) may be formed on sidewall of patterned photoresist 21 or be (located) formed on top of patterned photoresist 21. Further, particularly emphasized, trenches 22 are unavoidable defects during the formation of patterned photoresist 21(,) and (both location and shape of trenches) are randomly distributed.

Paragraph beginning at line 13 of page 6 has been amended as follows:

As shown in Fig. 2C and Fig. 2D, totally fills trenches 23 (to let all trenches 22 are totally filled) by the additional material 23. Herein, the available method for filling trenches 22 with the additional material 23 (at least) could be spin coating, dip, or spray. Moreover, to ensure the additional material 23 and patterned photoresist 21 (is effective) attaches(d) to each other effectively, the additional material 23 usually (are material which) could (be) adhere(d) to patterned photoresist 21 by chemical reaction, such as chemical bonding, or by physical adsorption, such as capiilary phenomena.

Paragraph beginning at line 22 of page 6 has been amended as follows:

The (A)additional material 23 (usually is)could be a fluid material, such as a solution and/or a suspension, to ensure to fill all trenches (are) totally (filled by additional material 23). Moreover, the additional material 23 could be a thermosetting polymer, a thermoplasticity polymer, and/or any material

which could (be) react(ed) with hydroxyl group or proton in patterned photoresist 21. Possible materials of the additional material 23 (at least) include at least one of the following materials: PMMA, POLY IMIDE, RELACS, a material with a functional group of -NH groups, and a material with a functional group of -OH groups. Herein, PMMA, POLY IMIDE, and RELACS (all are) is well-known materials (of) during the current semiconductor fabrication, for example, RELACS is a electronic materials which is produced by Clariant Inc.(its applications are not declared as what this invention.)

Paragraph beginning at line 6 of page 7 has been amended as follows:

However, although the additional material 23 with higher fluidity is better for filling trenches, it (also) is possible that the additional material 23 (is)does not firmly (fixed)adhere to patterned photoresist 21, especially (is not firmly fixed to patterned photoresist 21)during the sequentially etch process or the implant process. (Thus, a)As shown in Fig. 3A(shows), the (is)present invention could further perform a treat process after the additional material 23 is filled, (to)and be (enhance) adhere(sion) well between patterned photoresist 21 and the additional material 23.

Paragraph beginning at line 14 of page 7 has been amended as follows:

As shown in patterned photoresist block 31 (shows), providing(e) a patterned photoresist with at least one trench.

Paragraph beginning at line 17 of page 7 has been amended as follows:

As fill block 32 shows, filling trenches to let trenches are totally filled by the additional material.

Paragraph beginning at line 20 of page 7 has been amended as follows:

As shown in enhance adhesion block 33(shows), treating the additional material to enhance the adhesion between the additional material and patterned photoresist. Herein, available methods for treating the additional material (at least) include at least one of following methods: thermal treatment, ultraviolet light curing, electrons beam curing, treatment of chemical reaction, and chemical reaction between numerous functional groups of patterned photoresist and numerous functional groups of the additional materials.

Paragraph beginning at line 28 of page 7 has been amended as follows:

Furthermore, (because it is hard to only)accuracy to fill the addition material 23 only on(into) trenches 22 but without (filling the additional material 23)on the surface of patterned photoresist and/or on the substrate is hard to be controlled.(, especially considers c) Cost of precisely filling(required for precisely filling) process is necessary to be reduced, and (reduction of)throughput of the filling process is necessary to be promoted. As shown in Fig. 3B(shows), (this)the present invention could further remove the(any) additional material 23 (which locates) that is formed on the surface of patterned photoresist 21 or on the substrate 20 (after all trenches 22 is filled), to prevent(ensure pattern formed by both the additional material 23 and)the patterned photoresist 21 form(is not) deformed, (at most is)or slightly widen.

Paragraph beginning at line 8 of page 8 has been amended as follows:

As shown in patterned photoresist block 31(shows), (provide)a patterned photoresist with at least one trench is provided.

Paragraph beginning at line 11 of page 8 has been amended as follows:

As shown in fill block 32(shows), (fill trenches to let)trenches are totally filled by the additional material.

Paragraph beginning at line 14 of page 8 has been amended as follows:

As shown in partial removal block 34(shows), (remove part)portions of the additional material(,) that (where removed part of the additional material is)are located on patterned photoresist and the substrate are removed.

Paragraph beginning at line 22 of page 8 has been amended as follows:

As shown in patterned photoresist block 31(shows), (provide)a patterned photoresist with at least one trench is provided.

Paragraph beginning at line 25 of page 8 has been amended as follows:

As shown in fill block 32(shows), (fill trenches to let)trenches are totally filled by the additional material.

Paragraph beginning at line 28 of page 8 has been amended as follows:

As shown in partial removal block 34(shows), (remove part)portions of the additional material(, where removed part of the additional material)that is located on patterned photoresist and the substrate are removed.

Paragraph beginning at line 4 of page 9 has been amended as follows:

As shown in enhance adhesion block 33(shows), treating the additional material to enhance the (let that)adhesion between the additional material and patterned photoresist (is enhanced)after forming the additional material(is treated). Herein, available methods for treating the additional material (at least))include at least one of following methods: thermal treatment, violet light curing, electrons beam curing, treatment of chemical reaction, and chemical reaction between numerous functional groups of patterned photoresist and numerous functional groups of the additional materials.